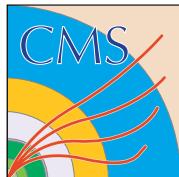


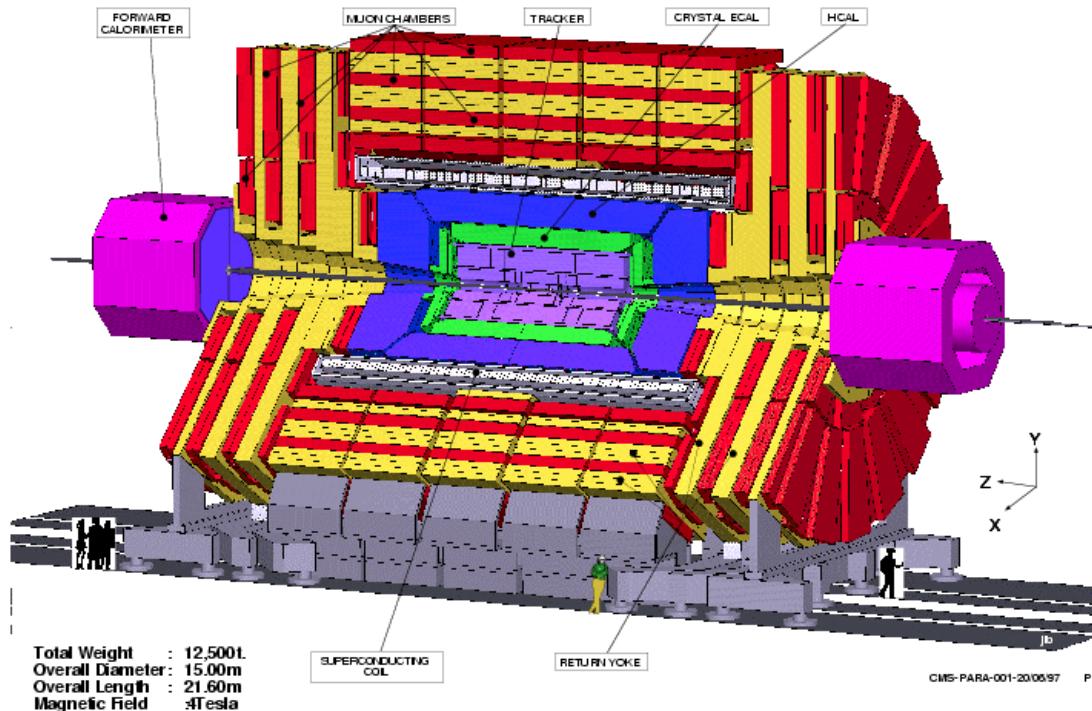
# Search for the Higgs Boson in $W^+W^-$ Decay Mode

Shuichi Kunori  
U of Maryland / CMS  
7-July-2003

CMS detector  
SM Higgs Production and Decay  
 $H \rightarrow WW$   
Analysis of  $qqH(120) \rightarrow WW$   
Conclusions



# The CMS detector



Total weight	12500 t
Overall diameter	15 m
Overall length	21.6 m

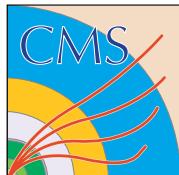
All silicon tracker  
micro strips (10M ch)  
pixel (40M ch)  
(5.4m long, 2.4m  $\Phi$ :  $|\eta| < 2.4$ )

Hermetic calorimeter  
ECAL: PbWO<sub>4</sub> crystal  
HCAL: brass+scint.  
(  $|\eta| < 3.0$  )

in 4 Tesla solenoid  
(12.5m long, 6m  $\Phi$  inner)

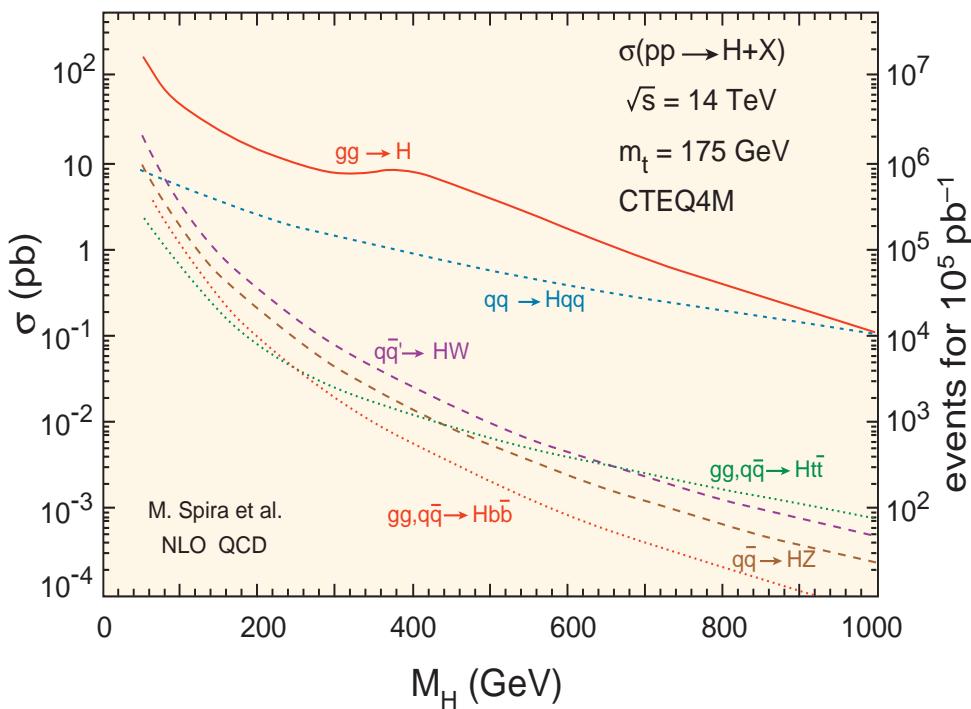
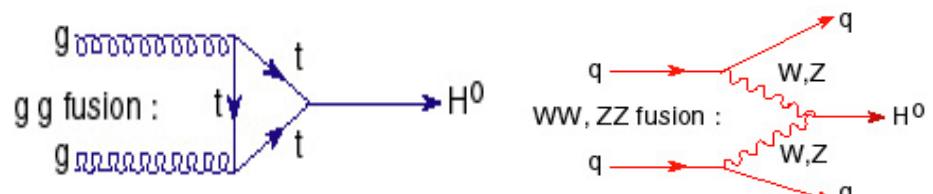
Robust muon system  
DT+RPC (barrel)  
CSC+RPC (endcap)  
(in iron yoke:  $|\eta| < 2.4$ )

Fast cerenkov calor.  
quartz fiber  
(  $3 < |\eta| < 5$  )

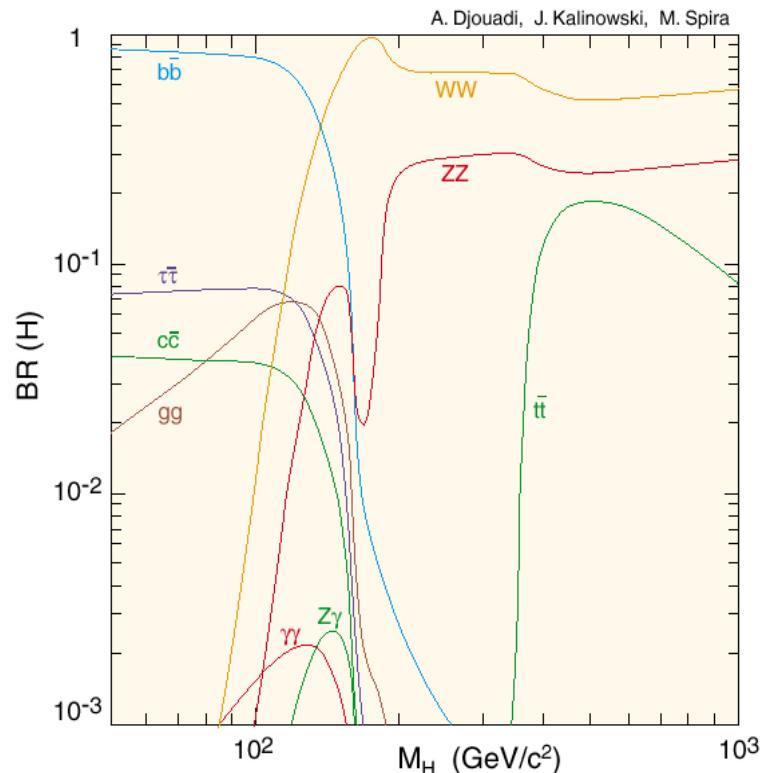


# SM Higgs

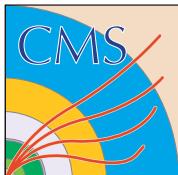
## production



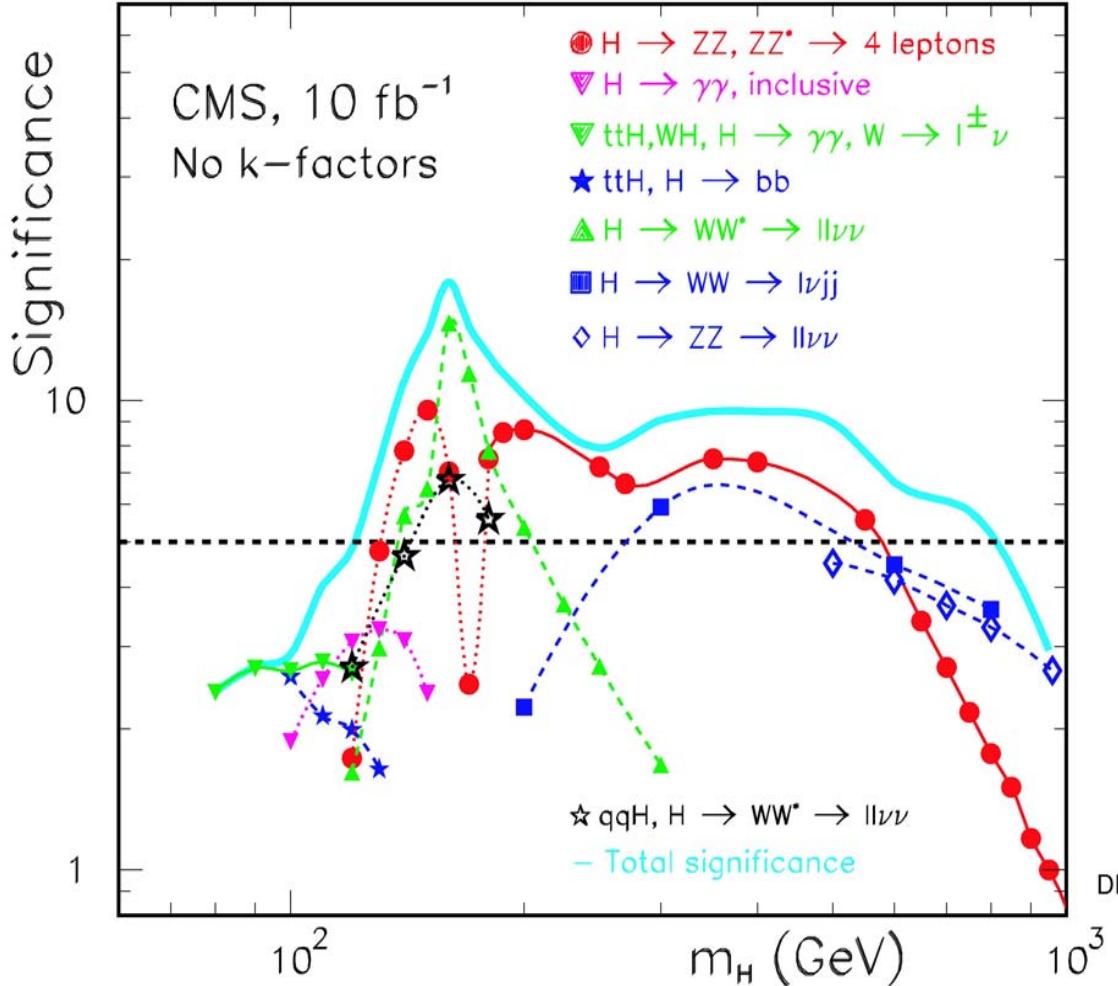
## decay



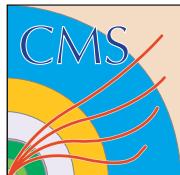
$\text{BR}(H \rightarrow WW)$	
120 GeV	12%
140 GeV	48%
160 GeV	92%



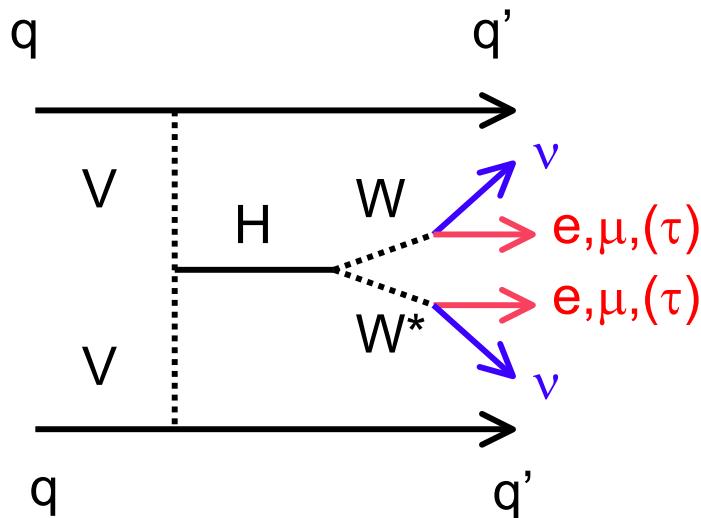
# $H_{\text{SM}} \rightarrow W^+W^-$



- 1) High Mass ( $>600\text{GeV}$ )  
WW/ZZ fusion  
 $qqH \rightarrow WW \rightarrow l\nu jj$
  - 2) Around 170GeV (155-180)  
gluon fusion  
 $H \rightarrow WW \rightarrow l\nu l\nu$ 
    - Dittmar, Dreiner, PRD 55,167 (1997)
  - 3) Low Mass (115-200GeV)  
WW/ZZ fusion  
 $qqH \rightarrow WW \rightarrow l\nu l\nu$ 
    - Rainwater, Zeppenfeld  
hep-ph/9906218 (1999)
    - Kauer, Plehn, Rainwater, Zeppenfeld  
hep-ph/0012351 (2000)
- 5 $\sigma$  with  $35\text{fb}^{-1}$  for  $H(115)$



# qqH(120) $\rightarrow$ WW $\rightarrow$ l $\nu$ l $\nu$



## Signal

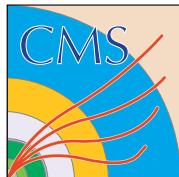
- two forward tagging jets
- no extra central jet
- two leptons  
soft lepton from  $W^*$  decay
- $M_T(WW)$

## Background

	Kauer et.al
tt $\rightarrow$ WbWb	2%
ttj $\rightarrow$ WbWb+j	50% (this analysis)
ttjj $\rightarrow$ WbWb +jj	11%
WWjj	25% (in progress)
$\tau\tau jj$	
lljj	

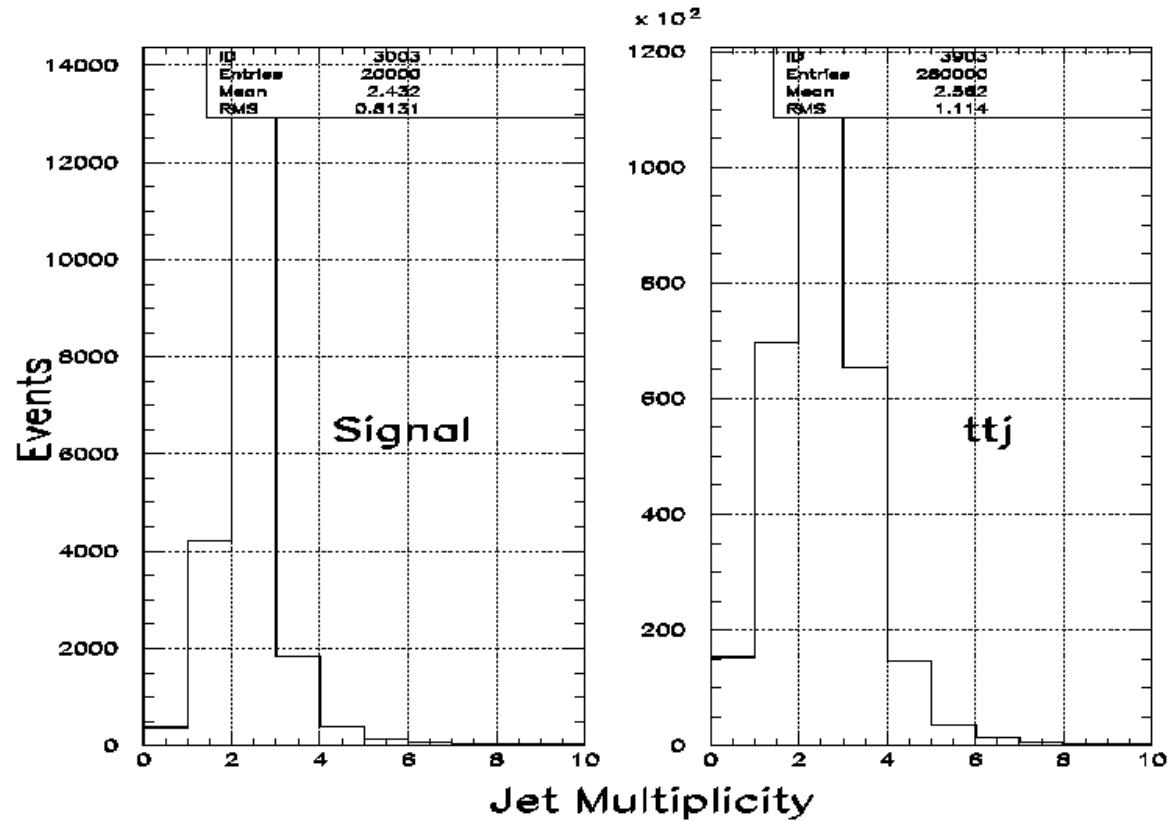
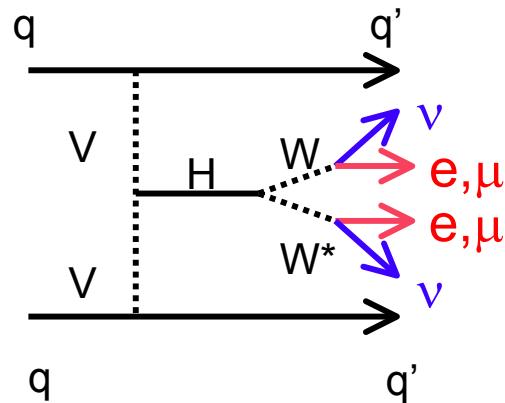
## Simulation

CompHEP+PYTHIA  
CMSIM(GEANT3)  
for  $2 \times 10^{33} \text{ cm}^{-2} \text{s}^{-1}$



# Jet Multiplicities ( $E_T > 20\text{GeV}$ )

Jet Reconstruction  
ORCA (CMS)  
Cone algorithm  
 $\Delta R < 0.5$



→Forward Tagging Jets

highest  $E_T$  jets in  $\eta > 0$  and  $\eta < 0$

$E_{Tj} \geq 20\text{ GeV}$ ,  $|\eta_{j1}| \leq 4.5$ ,  $\Delta R_{jj} \geq 0.6$

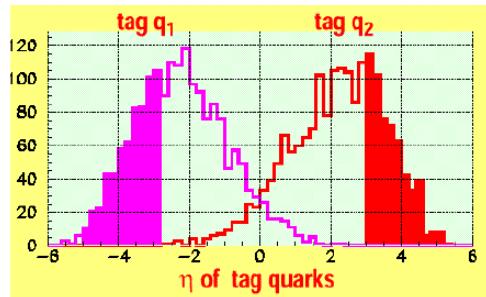
$|\eta_{j1} - \eta_{j2}| \geq 4.2$  and  $\eta_{j1} \cdot \eta_{j2} < 0$



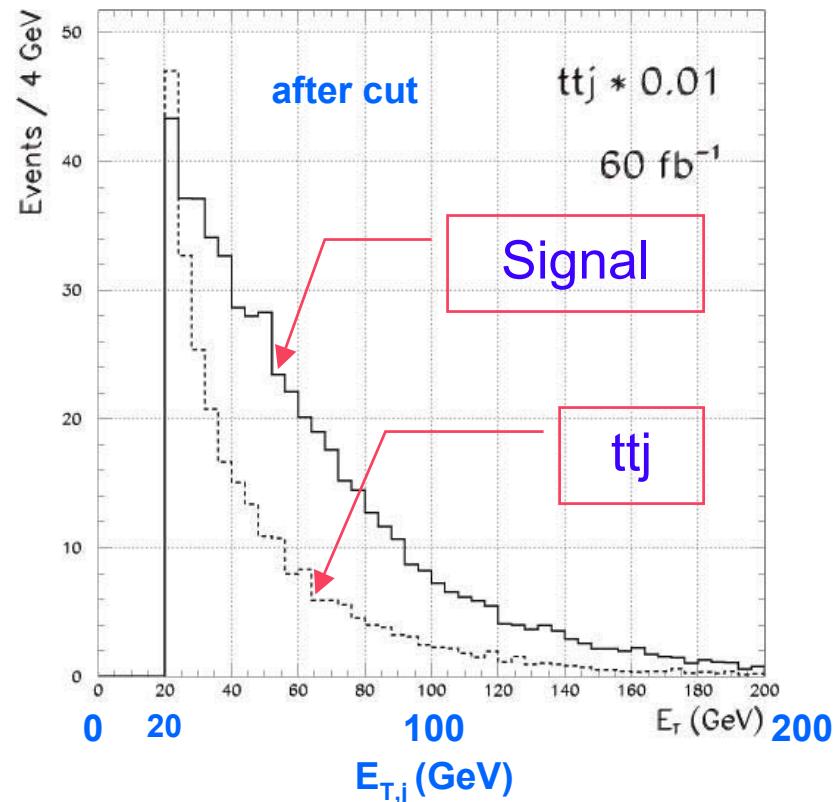
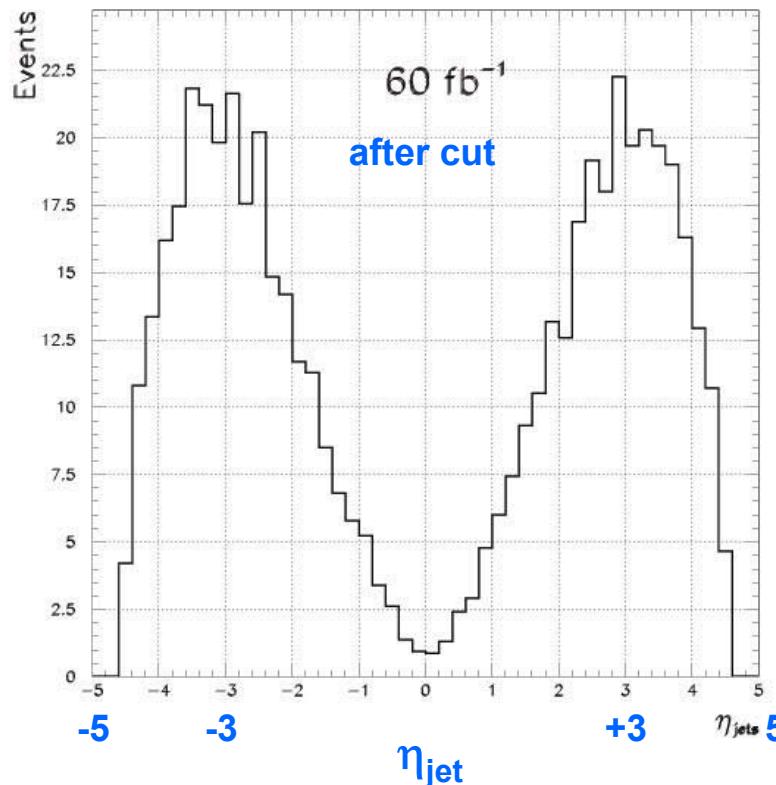
# Forward Tagging Jets

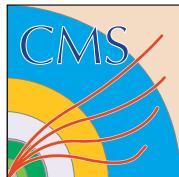
## - after forward jet tagging selection -

Generated  
quarks



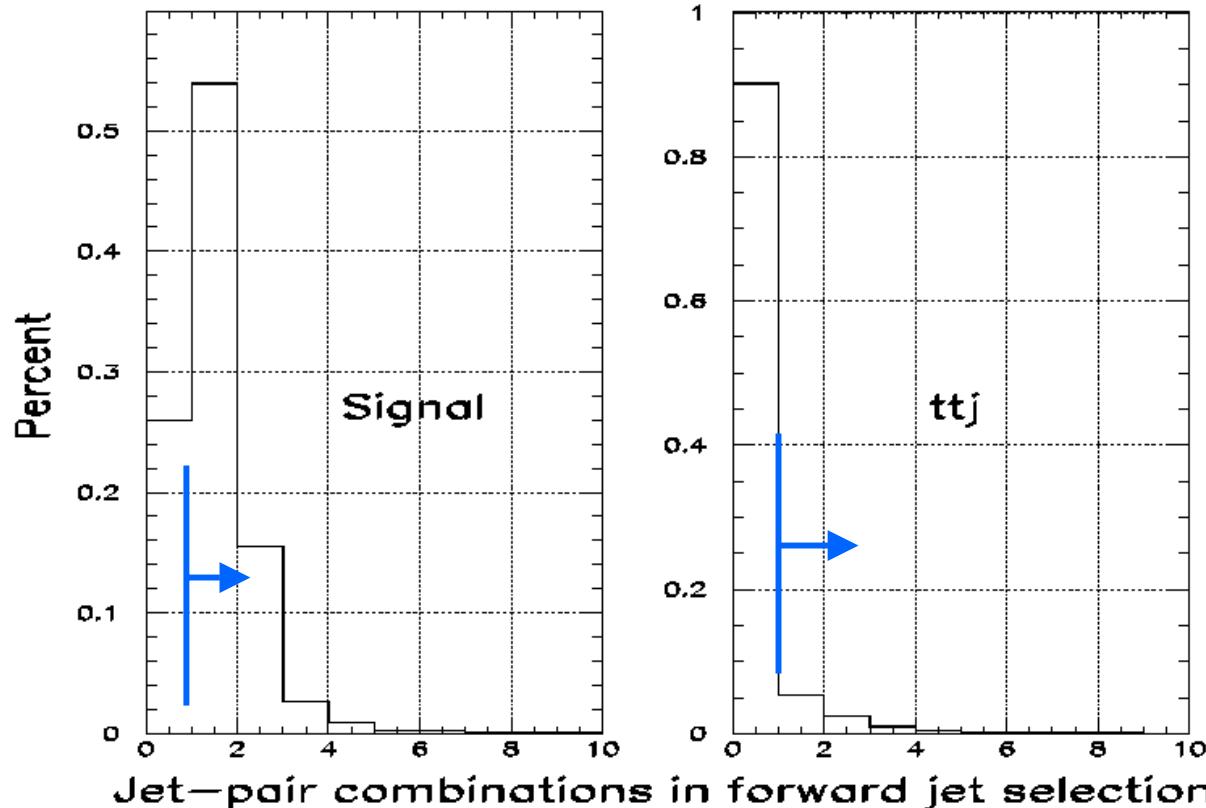
highest  $E_T$  jets in  $\eta > 0$  and  $\eta < 0$   
 $E_{T,j} \geq 20 \text{ GeV}$ ,  $|\eta_j| \leq 4.5$ ,  $\Delta R_{jj} \geq 0.6$   
 $|\eta_{j1} - \eta_{j2}| \geq 4.2$  and  $\eta_{j1} \cdot \eta_{j2} < 0$





# Forward Tagging Jets

- after forward tagging jets selection-



1 pair or more: 74%

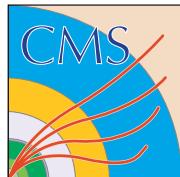
(ratio)

9.40fb  
(1)

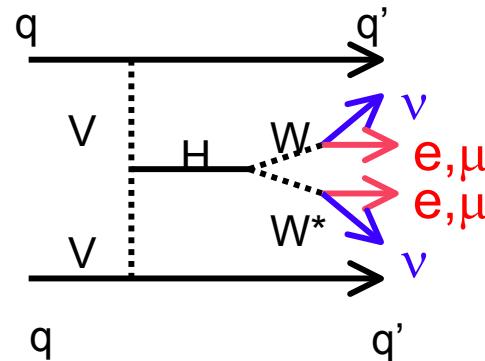
10%

3620fb  
(385)

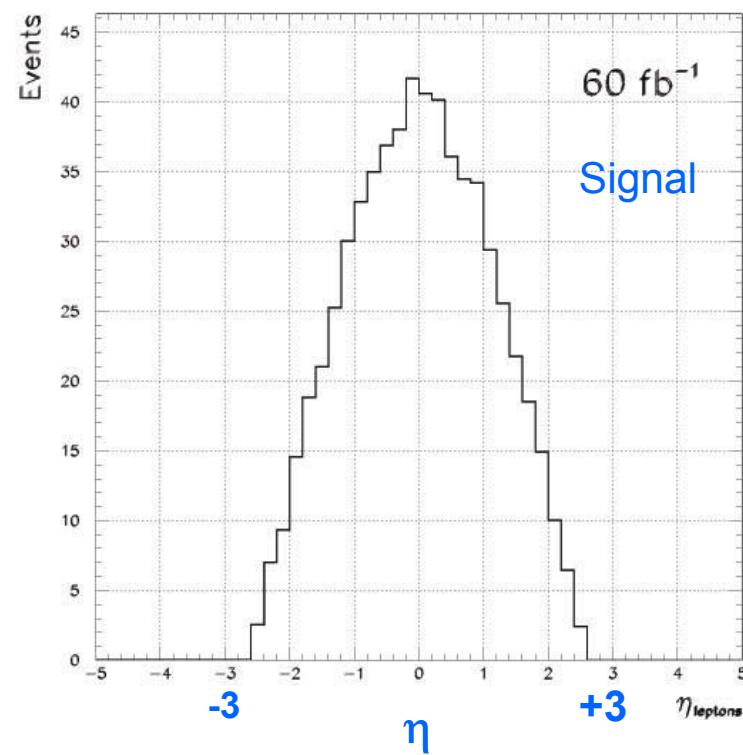
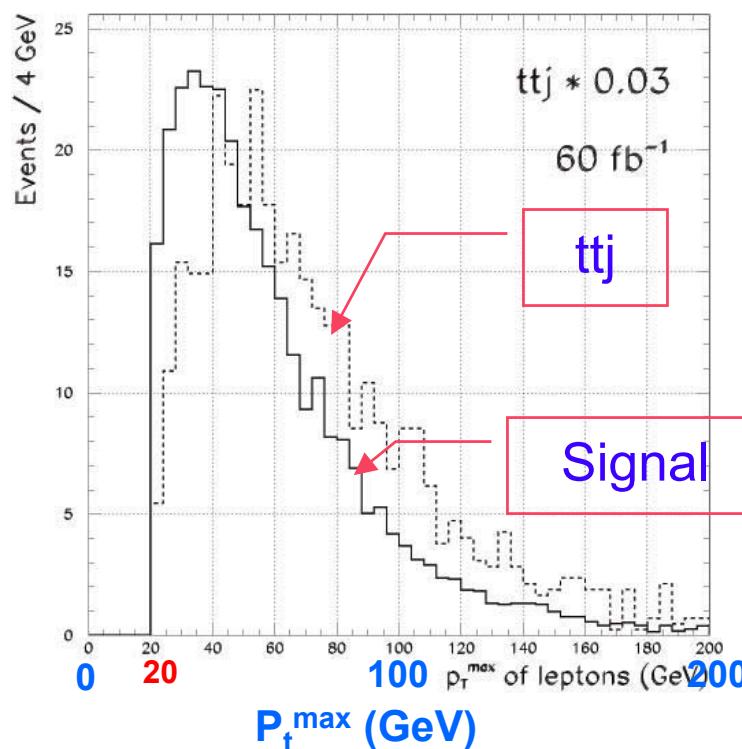
→ Lepton cuts

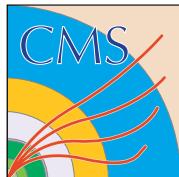


# Leptons



$P_{tl} \geq 20, 10 \text{ GeV}$ ,  $|\eta_{ll}| \leq 2.5$ ,  $\Delta R_{jl} \geq 0.7$   
 $\eta_{j,min} + 0.6 < \eta_{ll} < \eta_{j,max} - 0.6$

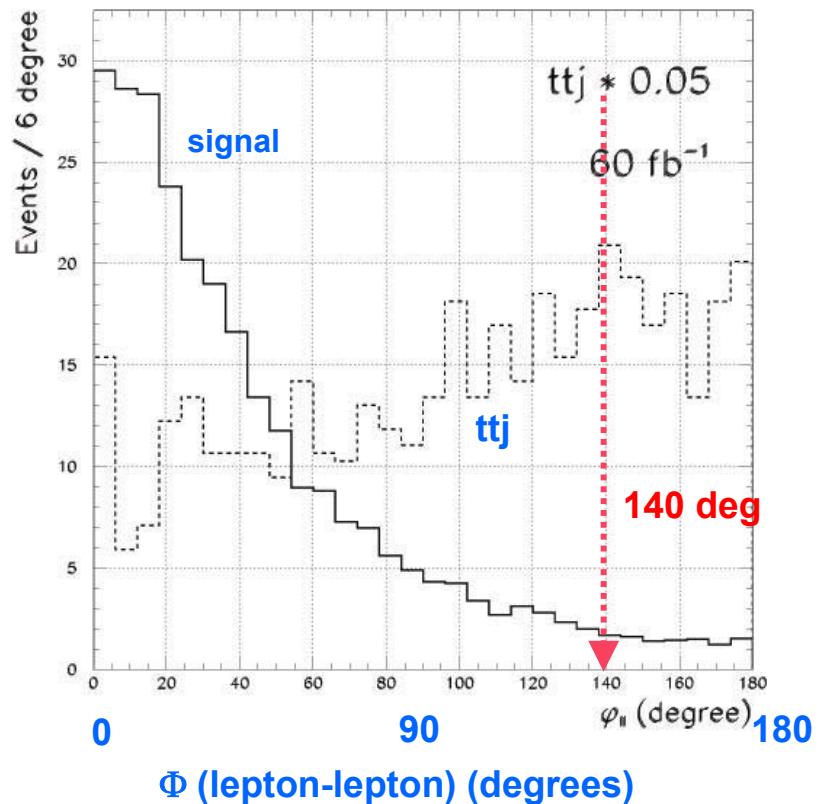
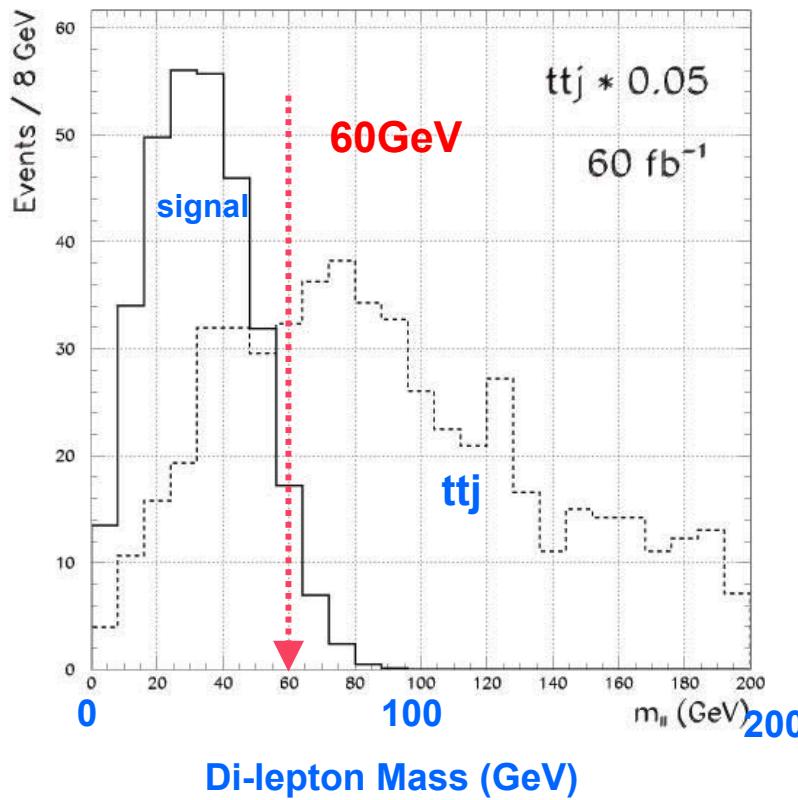


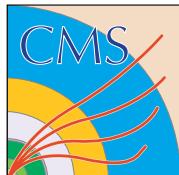


# di-lepton correlation

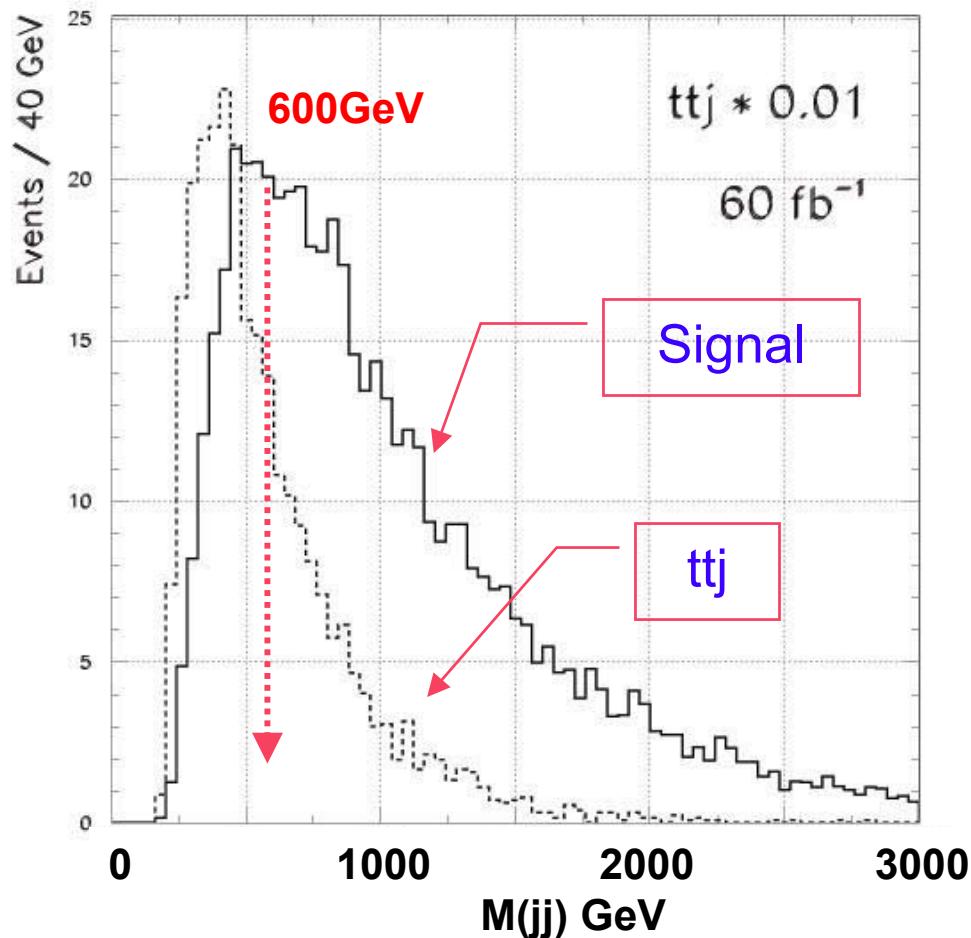
W's – produced close to the threshold, i.e. almost at rest in the Higgs frame.  
– spin correlation

→ lepton & neutrino      back-to-back  
→ lepton(+) & lepton(-)      same direction





# Invariant dijet mass ( $m_{jj}$ )



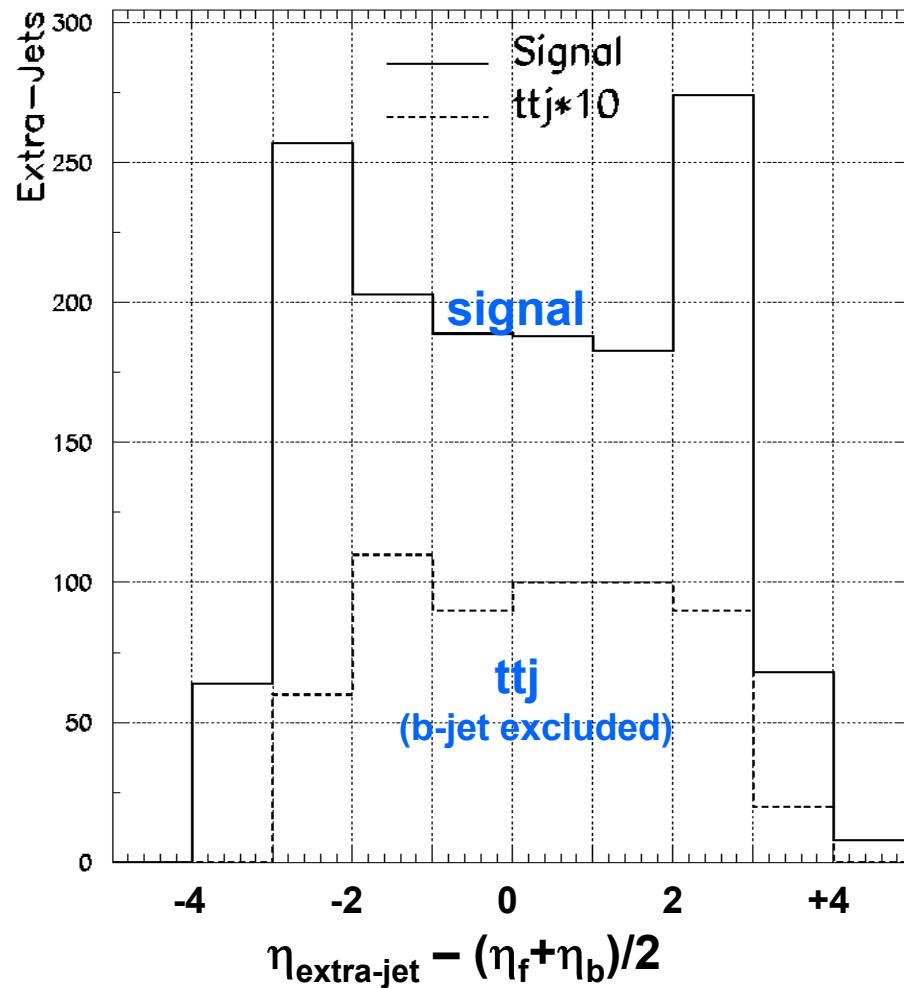
Additional selection  
for forward tagging jets

$M_{jj} > 600\text{ GeV}$

efficiency  
signal: ~80%  
bg: ~30%



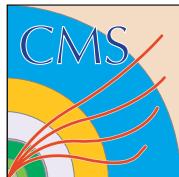
# Central jet veto



Central jet veto:  $E_T > 20\text{GeV}$

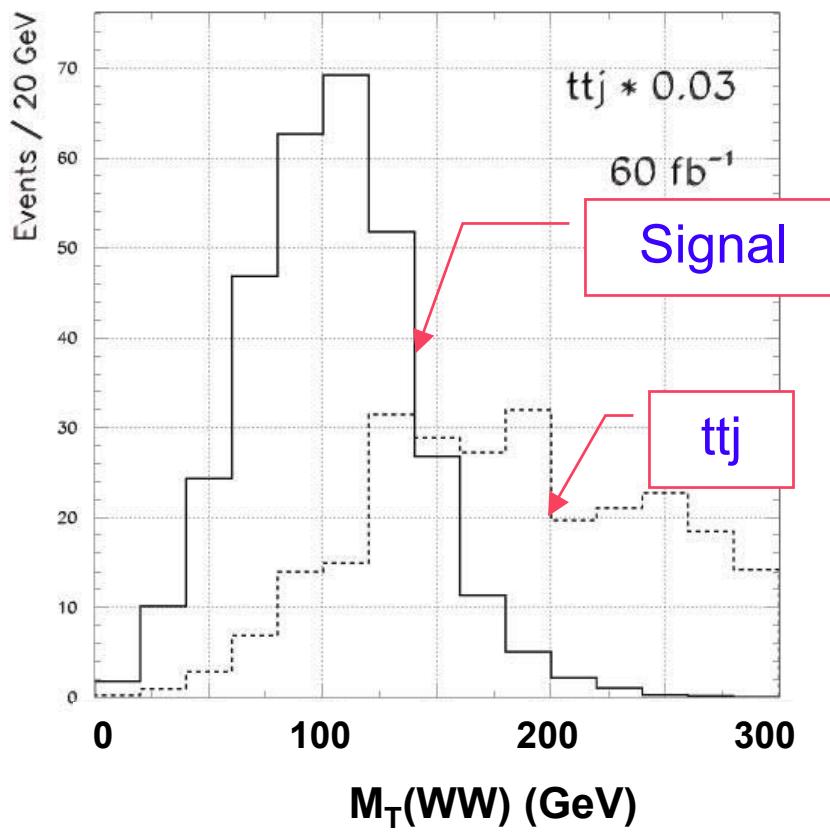
Efficiency  
bg (b-jets): 15%  
  
signal: 87%  
bg(non-b): 76%

Extra jets are soft.  
30GeV cut does not provide enough background rejection.

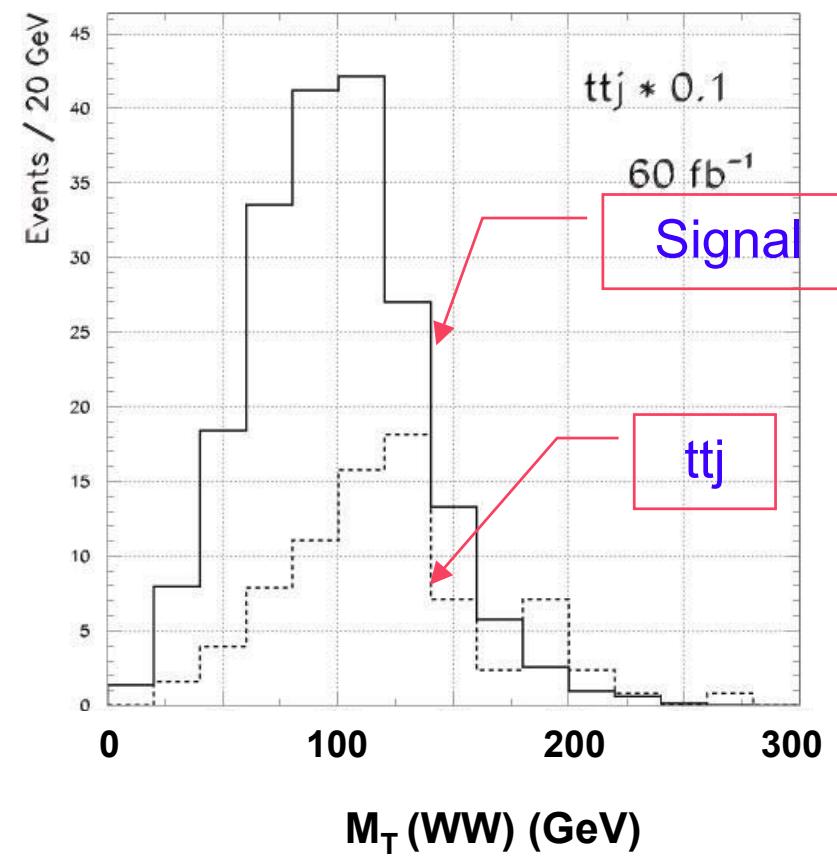


# Transverse Mass: $M_T(WW)$

Without Mass(II) and  $\phi$ (II) cuts

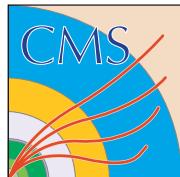


After all cuts



$$m_T(WW) = \sqrt{(E_T + E_{T, ll})^2 - (\vec{p}_T + \vec{p}_{T, ll})^2}$$

$50 < M_T < 140 \text{ GeV}$

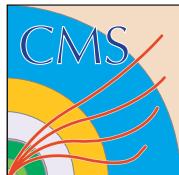


# Cross Sections and Selection Efficiencies

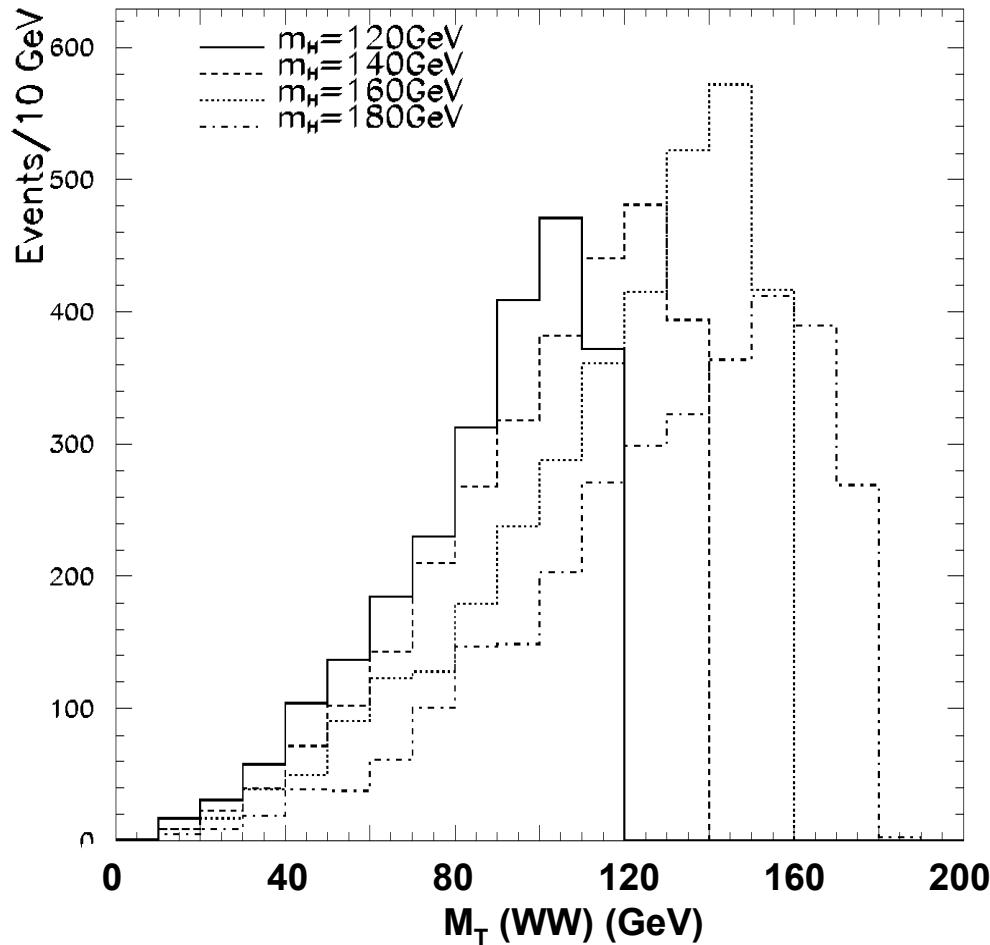
	Signal (12.7 fb)	ttj (36800 fb)
Jet tagging	9.40 (74.0%)	3620 (9.84%)
b-jet veto	9.40 (74.0%)	534 (1.45%)
Lepton isolation	5.25 (41.3%)	199 (0.54%)
$\phi_{\parallel}$ and $m_{\parallel}$ cuts	4.17 (32.8%)	41 (0.11%)
$m_{jj}$	3.26 (25.7%)	13 (0.035%)
extra-jet veto	2.84 (22.0%)	9.86 (0.027%)
$M_T(WW)$ cut	2.24 (17.6%)	6.83 (0.019%)

5 $\sigma$  luminosity is 34 fb $^{-1}$

Total background is  $< \times 2 \rightarrow < 68$  fb $^{-1}$  for 5 $\sigma$



# $120 < M_H < 180 \text{ GeV}$

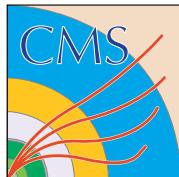


Using same event selection.

Required luminosity for  $5\sigma$ .

bg: ttj-only all

$120 \text{ GeV}$	$34$	$< 68 \text{ fb}^{-1}$
$140 \text{ GeV}$	$11$	$< 22 \text{ fb}^{-1}$
$160 \text{ GeV}$	$5$	$< 10 \text{ fb}^{-1}$
$180 \text{ GeV}$	$7$	$< 14 \text{ fb}^{-1}$



# Conclusions

Higgs production through WBF gives a very clear signal topology.

Based on the analysis with the largest back ground channel ( $t\bar{t}j$ ), we estimated the required luminosities for  $5\sigma$  discovery to be

$< 70 \text{ (10)} \text{ fb}^{-1}$  for  $M_H=120 \text{ (160)} \text{ GeV}$

The significance level is less than that shown in the paper by Kauer et al., but it is still a promising channel to detect low mass Higgs.

Study with other background channels and optimization of event selection are in progress.

Since the  $M_T$  distribution is not much different in shape for signal and background after all cuts, it is important to have excellent understanding of background experimentally.